The Influence of Negative Heels on Plantar Foot Pressures during Treadmill Walking

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Introduction:

- Plantar foot pressures reflect general loading patterns of the foot (Cavanagh et. al. 1992)
- Deviation from a flat surface
  - yields a different pressure pattern
  - therapeutic value

Purpose

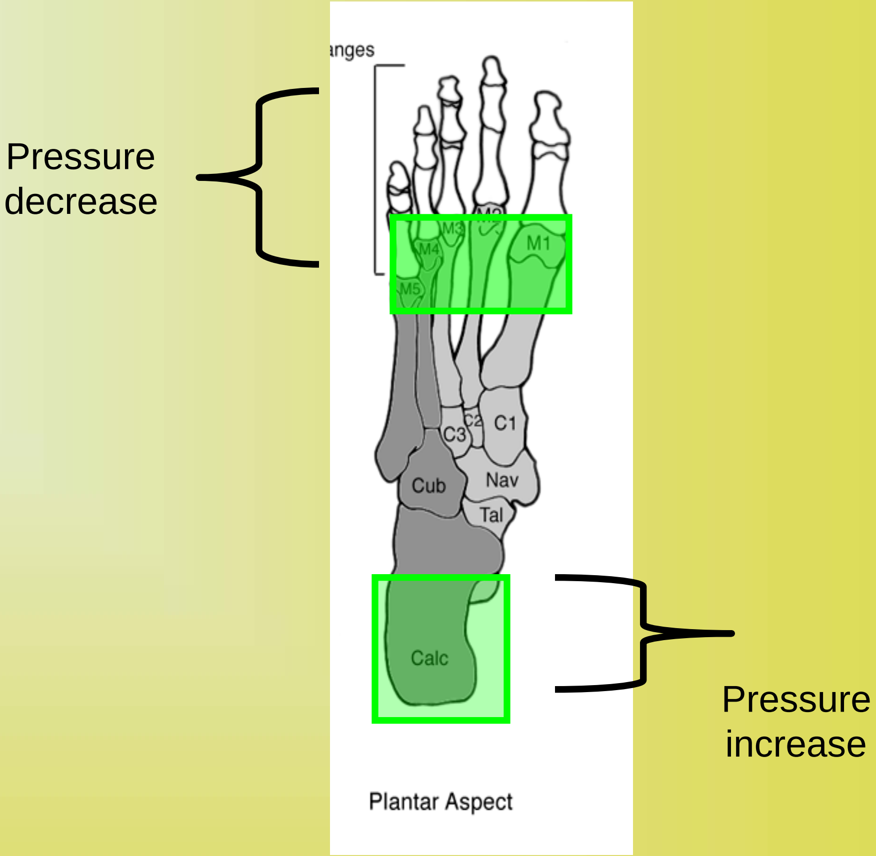
- To **evaluate** the **influence** of a **negative heel** on plantar foot pressures during walking in healthy subjects
- **Observe** the **mechanics** of how the foot **responds** with regard to **loading**

Pressures Measurements

- Factors play a role in plantar pressures (Burnfield et al 2003)
  - velocity
  - footwear
- Pressure is important when evaluating the effect a device (Neumann 2002)

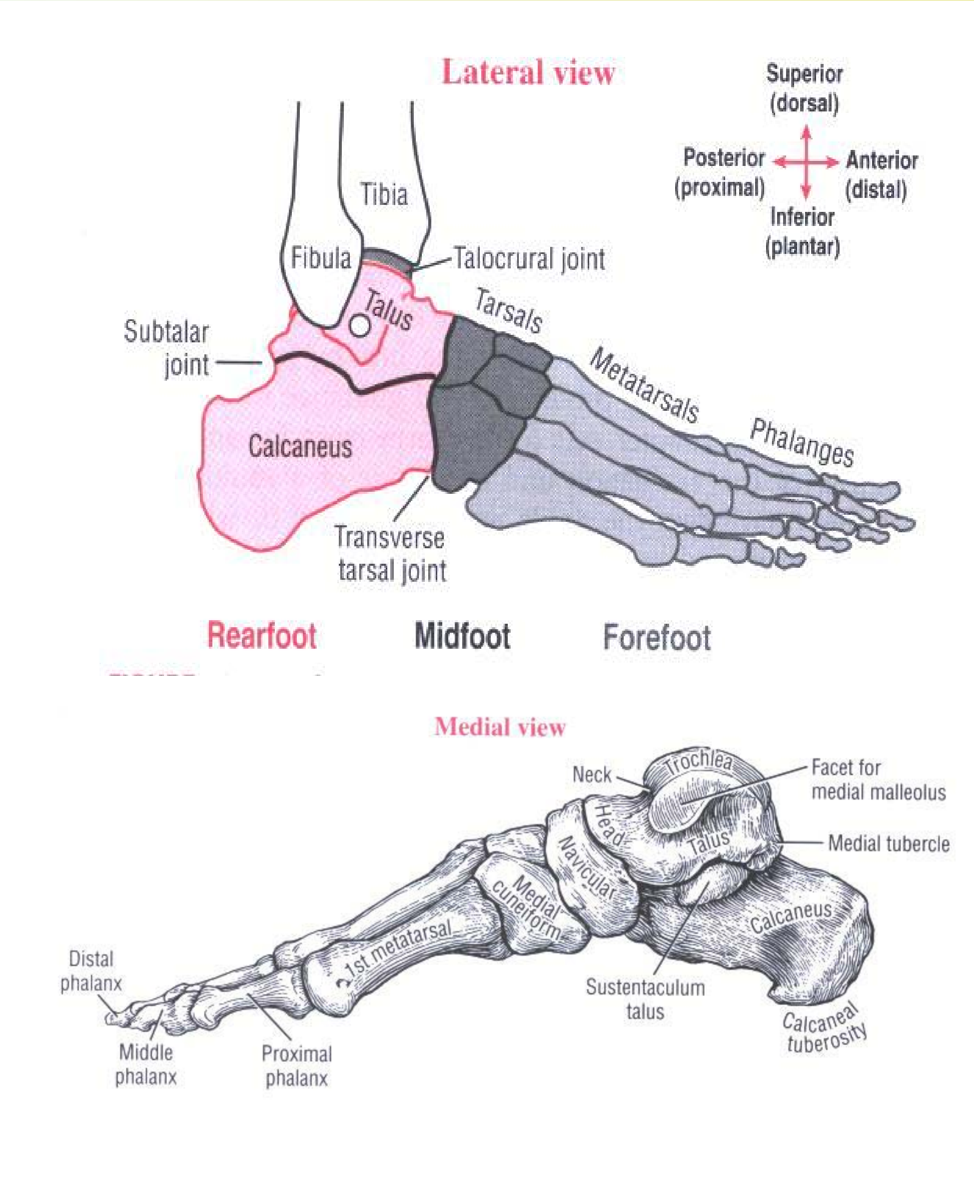
Hypothesis

- A **negative heel** on a shoe's sole will **decrease** forefoot **plantar pressures** and **increase** rearfoot (heel) **plantar pressures** during treadmill walking.



Foot Structure & Function

- **3 sections** (Neumann 2002)
  - **Rearfoot** – absorbs and transfers large loads
  - **Midfoot** – transfers loads and helps to lock/unlock the foot
  - **Forefoot** – leverage & balance
- Metatarsal heads (MTH)



The Negative Heel

- Negative heel position: the heel lower than forefoot when entire foot is on the ground
- Negative Heel = a wedge
  - elevates the entire forefoot

The High Heel

- **Increased pressures** at the **forefoot** - correlates with heel height (Witana et al. 2009, Ramanathan et al. 2008)
  - Logically a negative heel opposite effect?
- Plausible issues
  - Foot not designed to fully weight bear on forefoot
  - Western culture - shod society (shoe) that elevates the heel

Why a "Negative Heel"

- An increased popularity that claims "fitness" benefit
  - No evidence of effect on plantar pressures
  - Address the basic mechanics & loading
- One popular brand states a 3.7° negative heel wedge

Company claims

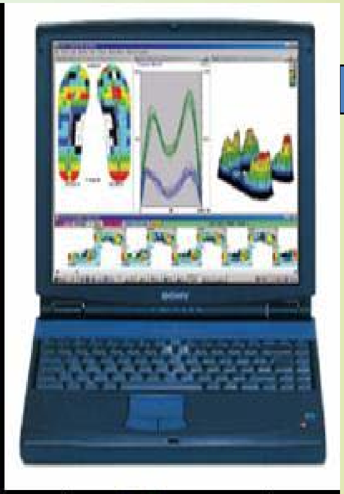
Methods:

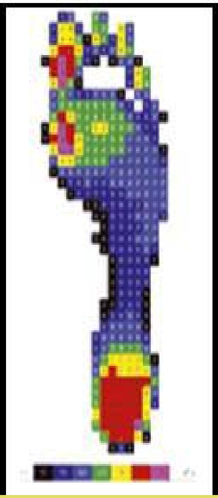
- Subjects:
  - 10 asymptomatic healthy volunteer subjects
    - 6 Female, 4 male
    - Each took survey, having no known neurological or orthopedic pathology = healthy
  - Ages: 19 to 27 years (mean = 23)
  - Capable of walking on a treadmill unaided
  - Ankle range of motion fell within normal limits while knee extended according to AAOS standards

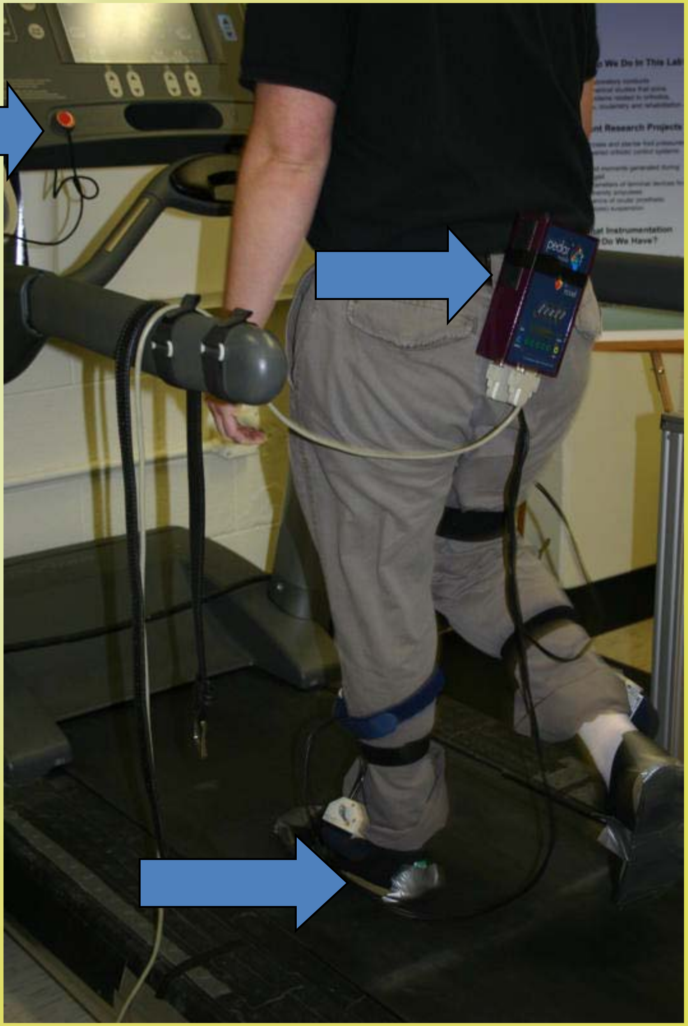
Methods

- 3 conditions
  - Control (flat with no wedge)
  - 2° inclined wedge
  - 4° inclined wedge
- Velocity
  - 1.3 m/s
    - Average self selected walking speed adults (Perry, 1992)
- Order of conditions were randomized
- Approved IRB

Plantar Measurement Tools

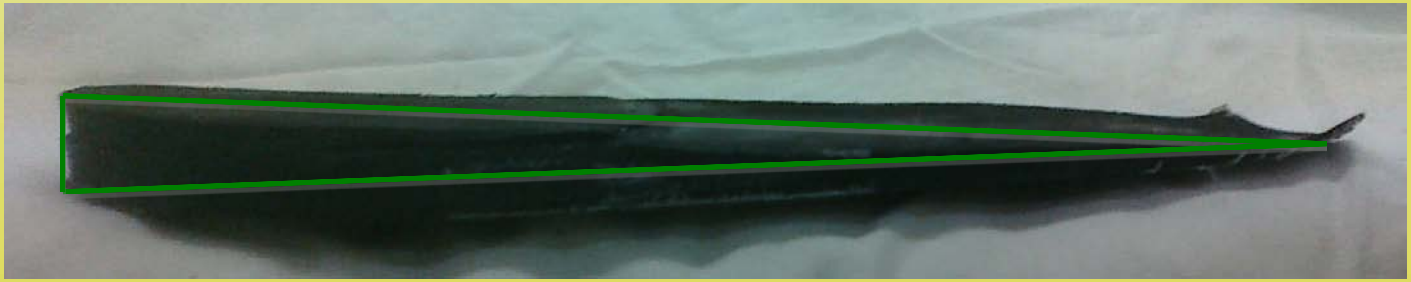






Materials

- Negative heel wedges:
  - Standard shoe soling material (SoleTech Salem MA)
  - Material properties- hardness (Shore A Durometer of 70 to 75) (i.e., firm)

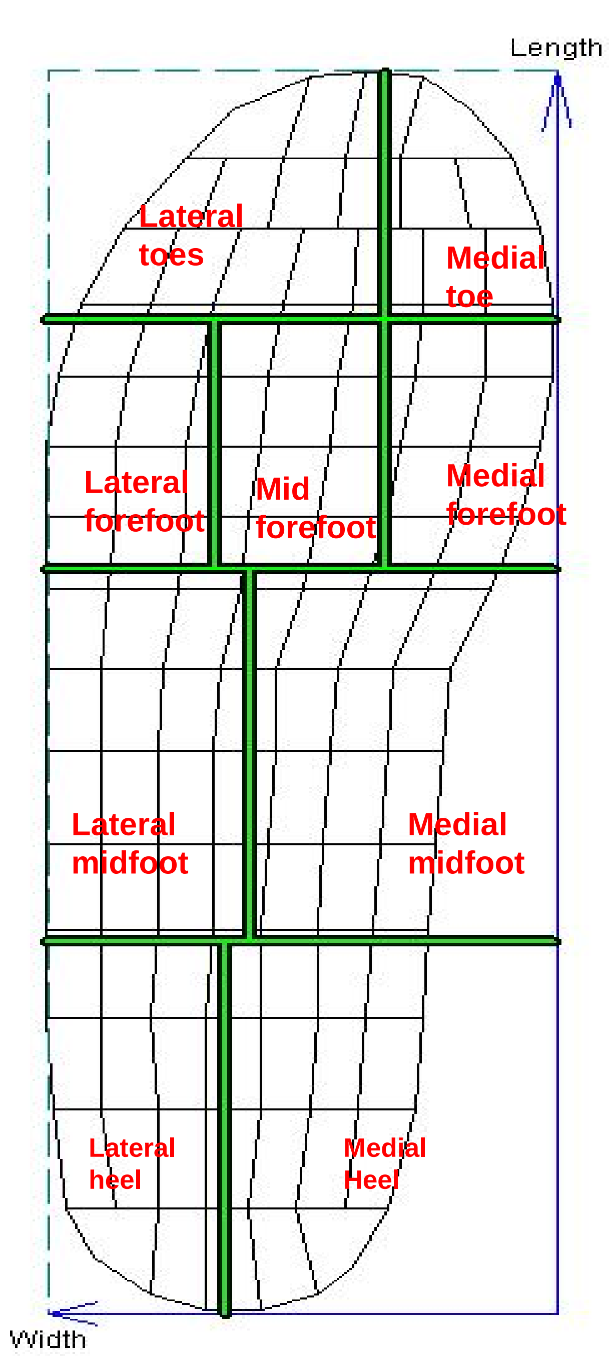


Analysis Method:

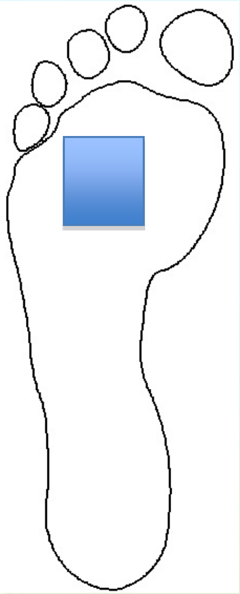
- Peak pressures averaged over range of 8 to 10 steps per subject
  - Only 3 or more steps required to establish reliable peak pressures (Hughs 1991)
- Compared all subjects across conditions and each region of the foot

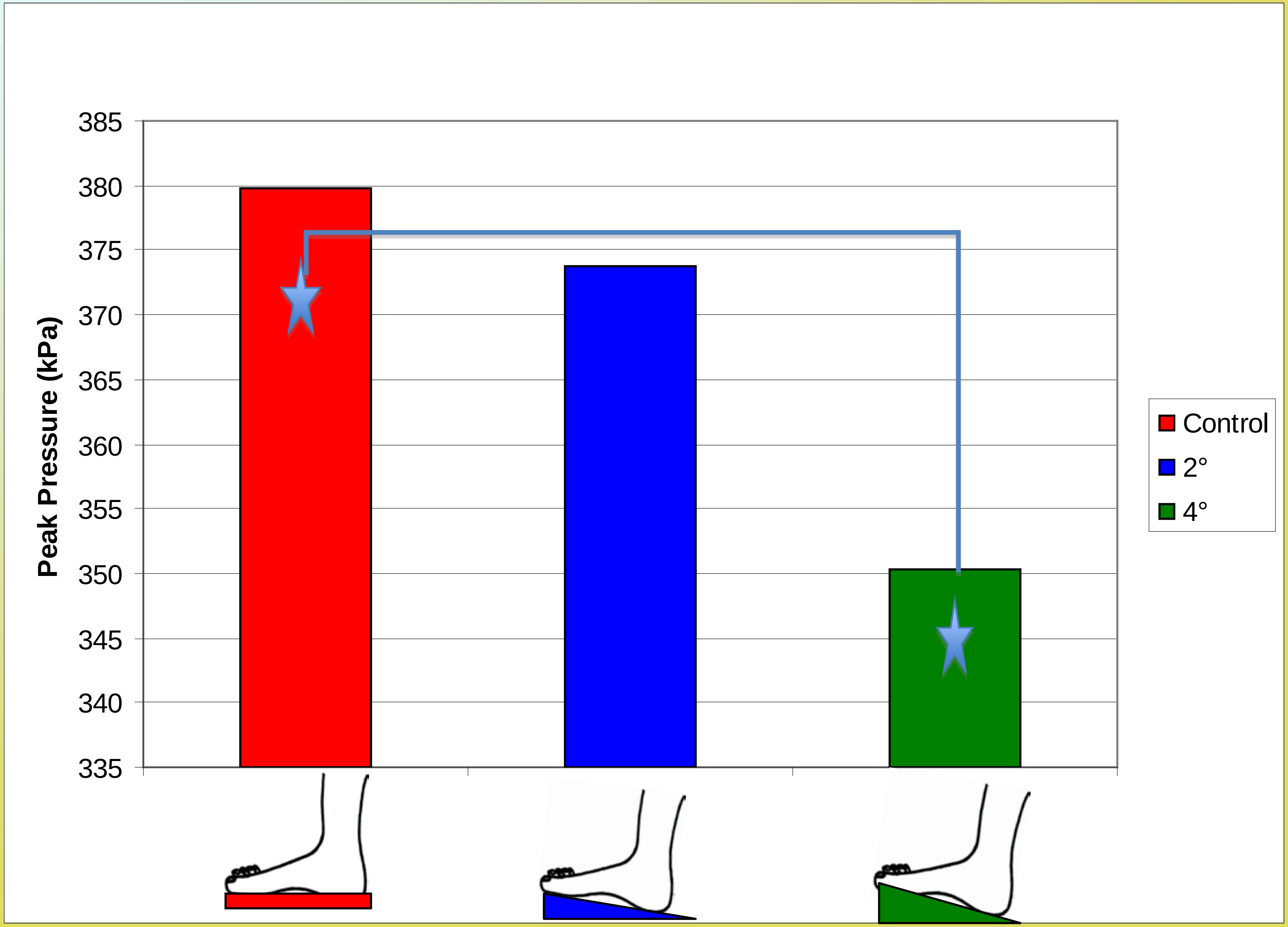
Data Analysis:

- 9 regions (Cavanagh 1992)
- Repeated measures ANOVA was performed in SPSS
  - Compared differences across all conditions
- Boneferroni Post-hoc
  - Significance p-value ≤ 0.05



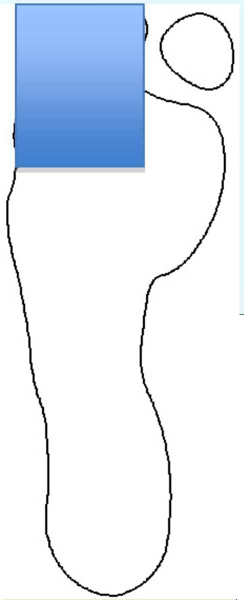
Results
Mid-Forefoot (2-3 MTHs)

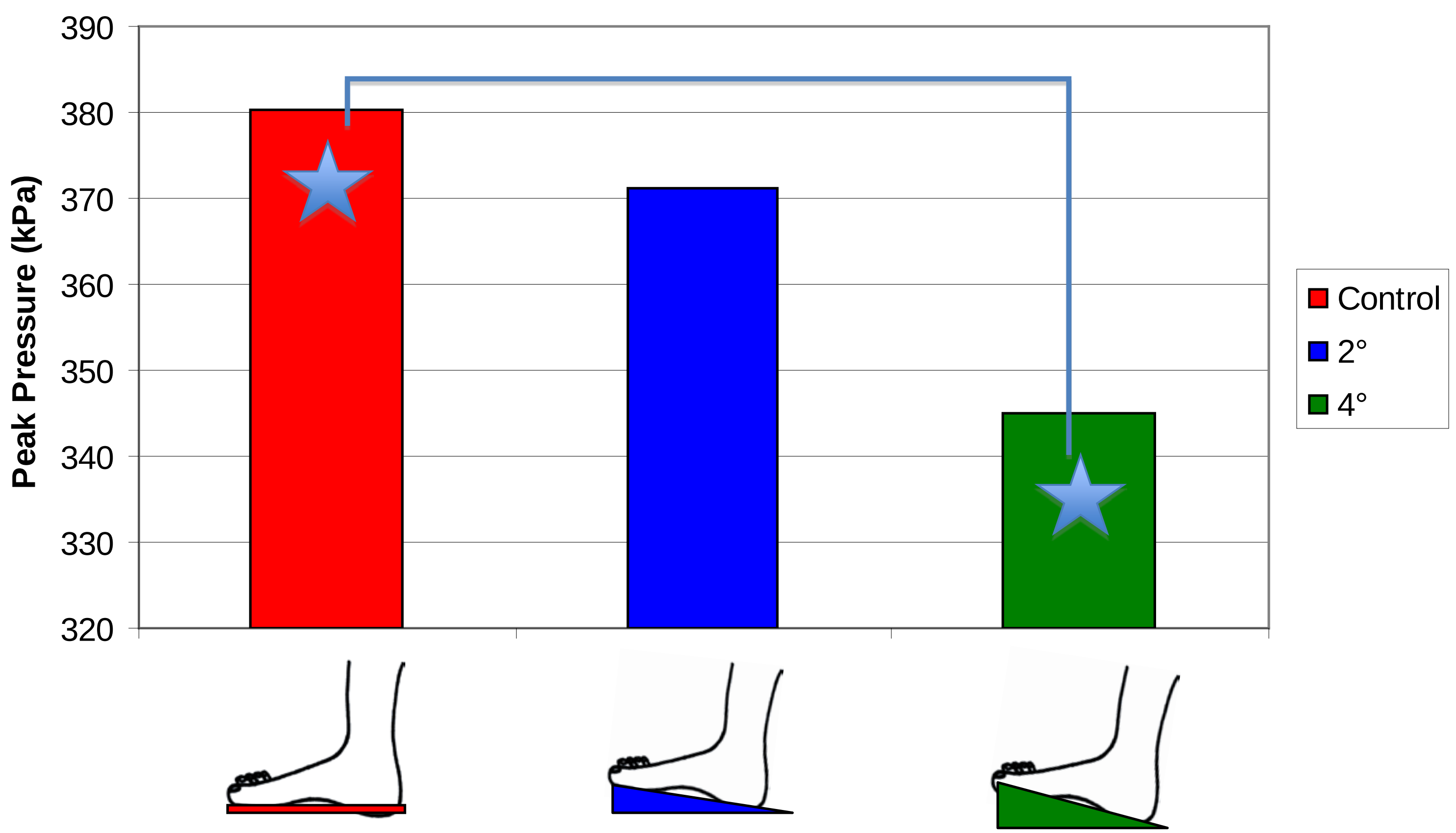




* $p \leq 0.05$

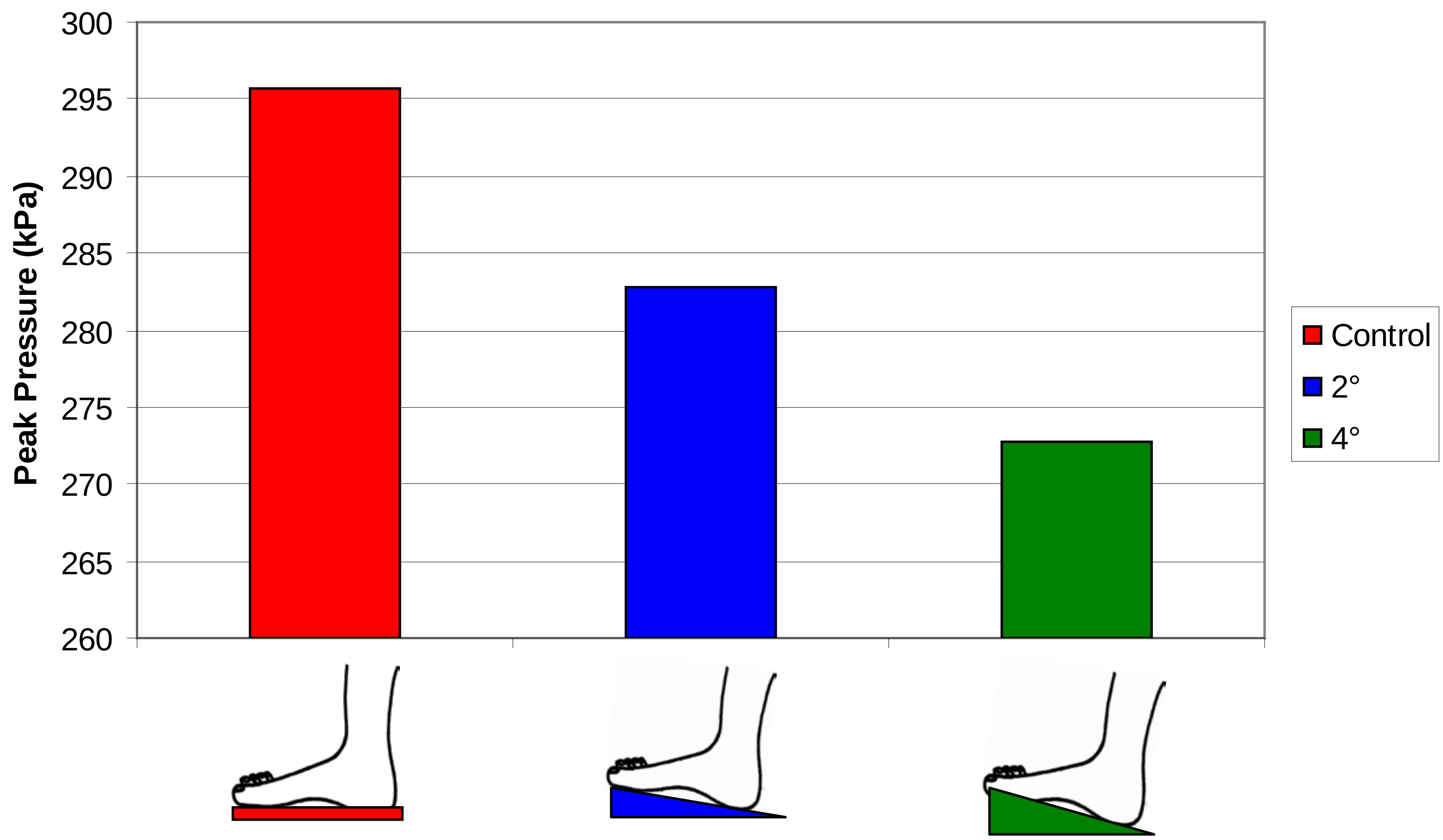
Results
Lateral Toes





* p ≤ 0.05

Results
Lateral Forefoot (4-5 MTHs)



* No signifigance

Discussion

- A **negative heel** on a shoe's sole will **decrease** forefoot **plantar pressure** and **increase** rearfoot (heel) **plantar pressures** during treadmill walking.
  supported
  - Partially supported
  - Peak pressures decreased at the forefoot (MTH 2-3)($p \leq 0.05$)
  - ~~Peak pressures at the heel were not significantly changed compared to the control~~

Discussion

- **Peak Pressures on Forefoot decreased** – forefoot loading pattern changed ($p < 0.05$)
- The medial and lateral heel appear to bear a greater portion of the load compared to the control (no forefoot elevation)
- Pressure pattern adopts a **Posterior Shift** in plantar foot loading with regard to peak pressures

Discussion

- When the foot interacts with a negative heel interface, the loads shift from
  - mid forefoot, 2-3 MTH significantly ($p < 0.05$)
  - Lateral toes significantly ($p < 0.05$)
  - Lateral forefoot (lesser degree) 4-5 MTH

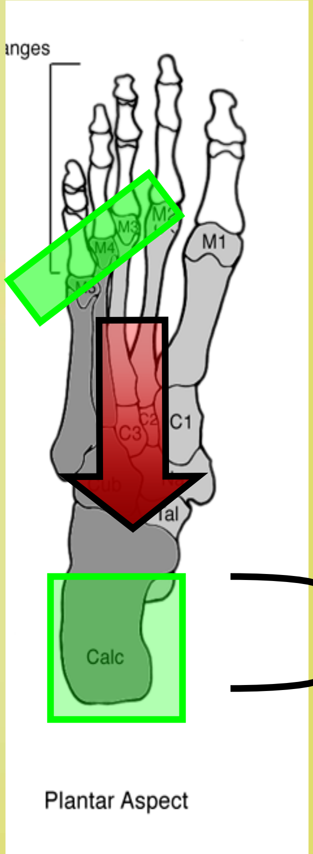
Discussion

- Polymodus Support – Multiple Load Transmission Strategies
  - The load transmission path of the foot will modulate as it adapts to a surface change through the use of different structural support mechanisms (Kogler et al., 1999)

Discussion

- Polymodus support
  - The mode that appears to be adopted is one that shifts loads away from the lateral MTH and increases loading to the heel
  - Results from this study support that theory

Pressure decrease



Pressure increase

Discussion

- This study demonstrates the considerable differences in load redistribution on the plantar surface based on the design of the sole of the shoe
- This observation is also noted by other investigators who have shown that with elevation of the heel (i.e., high heeled shoes), where pressure increased at forefoot (Mandato & Nester, 1999).

Conclusion

- A negative heel results in a decrease in peak pressures at the 2nd - 3rd MTH and lateral toes compared to a planar level surface without a negative heel during treadmill walking.

Clinical Relevance

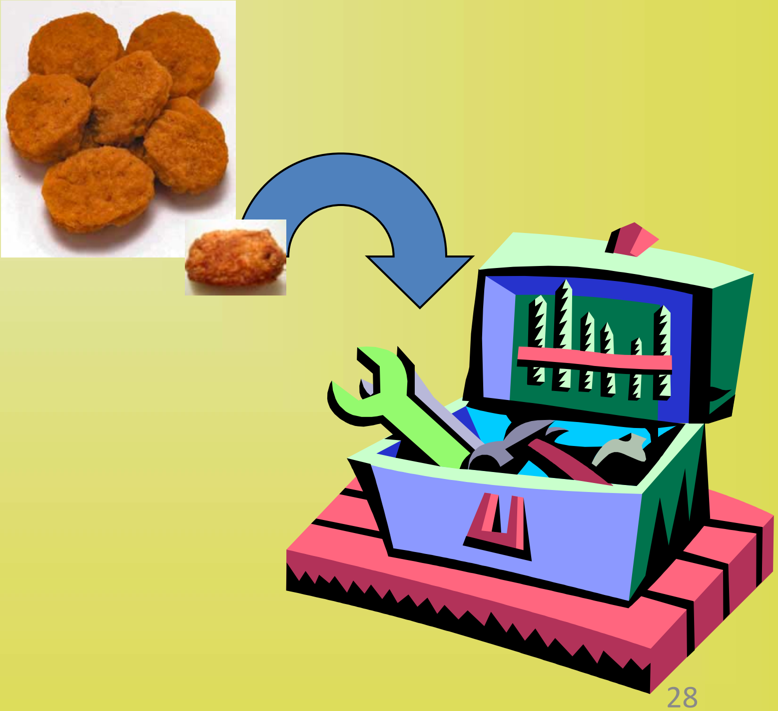
- Notable decreases in PP at the 2-3 MTH with a negative heel may be of value when targeted pressure redistribution is a clinical objective
- Examples:
  - Treating the diabetic foot, plantar ulcers (Ramanathan et al. 2008, Praet & Louwerens, 2003)
  - Relieve foot pain (e.g., metatarsalgia)
- This information may be important to (Janisse & Janisse 2008):
  - orthotic prescription formulation
  - shoe recommendations

Limitations & Future Studies:

- Only evaluated healthy, relatively young adults
  - future research should look at populations of different ages and those with different foot pathologies
- Structural stiffness of the foot was not controlled
- Kinematic and muscle activity measures (EMG) – other metrics to collect

Take Home Message

- The foot responds mechanically when the shoe is altered which can be evaluated quantitatively by plantar pressures
  - A negative heel may aid in reducing overall forefoot pressure
- Hopefully you have another “nugget” of knowledge to add to your clinical toolbox



References:

- Burnfield, J.M.; Few, C.D.; Mohamed, O.S.; Perry, Jacquelin. The Influence of walking speed and footwear on plantar pressures in older adults. J Clinical Biomech 2004; 19: 78-84. Neumann DA.
- Cavanagh, P.R., Hewitt, F.G., Perry, J.E. In-Shoe Plantar Pressure Measurement: A Review. The Foot 1992; 2:185-194.
- Hughs J., Pratt L., Linge K., Clark K., Klenerman L. Reliability of Pressure Measurements: the EMED F system. Clinical Biomech 1991; 6:14-18.
- Janisse D.J., Janisse E. Shoe Modification and the Use of Orthoses in the Treatment of Foot and Ankle Pathology. J Am Acad Orthop Surg 2008; 16(3):152-158.
- Kogler GF, Veer F, Solomonidis SE, Paul JP. The Influence of Medial and Lateral Placement of Orthotic Wedges on Loading of the Plantar Aponeurosis. In vitro study. J of Bone & Joint Surgery 1999; 81A: 1403-1413
- Mandato M.G., Nester E. The Effects of Increasing Heel Height on Forefoot Peak Pressure. J Am Podiatr Med Assoc 1999; 89(2):75-80.
- Neumann, Donald. Kinesiology of the Musculoskeletal System Foundations for Physical Rehabilitation. St. Louis: Mosby, Inc.; 2002.
- Praet, Stephan; Louwerens, Jan-Willem. The Influence of Shoe Design on Plantar Pressures in Neuropathic Feet. Diabetes Care 2003; 26(2):441-445.
- Perry, Jacquelin. Gait Analysis Normal and Pathological Function. Thorofare: Slack Inc.; 1992
- Ramanathan A.K., John, M.C., Arnold, G.P., Cochrane L., Abboud R.J. The Effects of Off-the-Shelf Heel Inserts on Forefoot Plantar Pressure. Gait & Posture 2008; 28:533-537.
- Witana, Channa, Goonetilleke, R.S., Yim Lee Au, E., Xiong, S., Lu, X. Footbed Shapes for Enhanced Footwear Comfort. Ergonomics 2009; 52(5):617-628.

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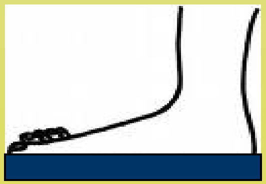
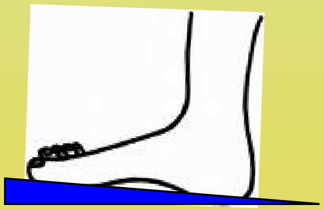
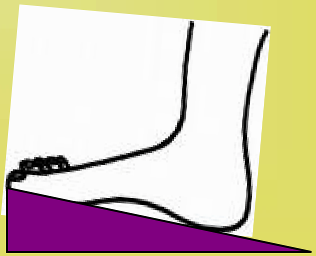
QUESTIONS??

Conditions







- Results are consistent in the literature that load bearing (PP) shift towards the heel when the forefoot is elevated with a rocker bottom type intervention (Praet and Louwerens 2003)
- Static loading on forefoot increases with increasing heel height (Snow and Williams 1994 & Witana et al. 2009)

- A study by Witana et al 2009 found that pressures
  - not exceeding 255 kPa no pain clinically
  - Assuming pain pressure thresholds from the hand